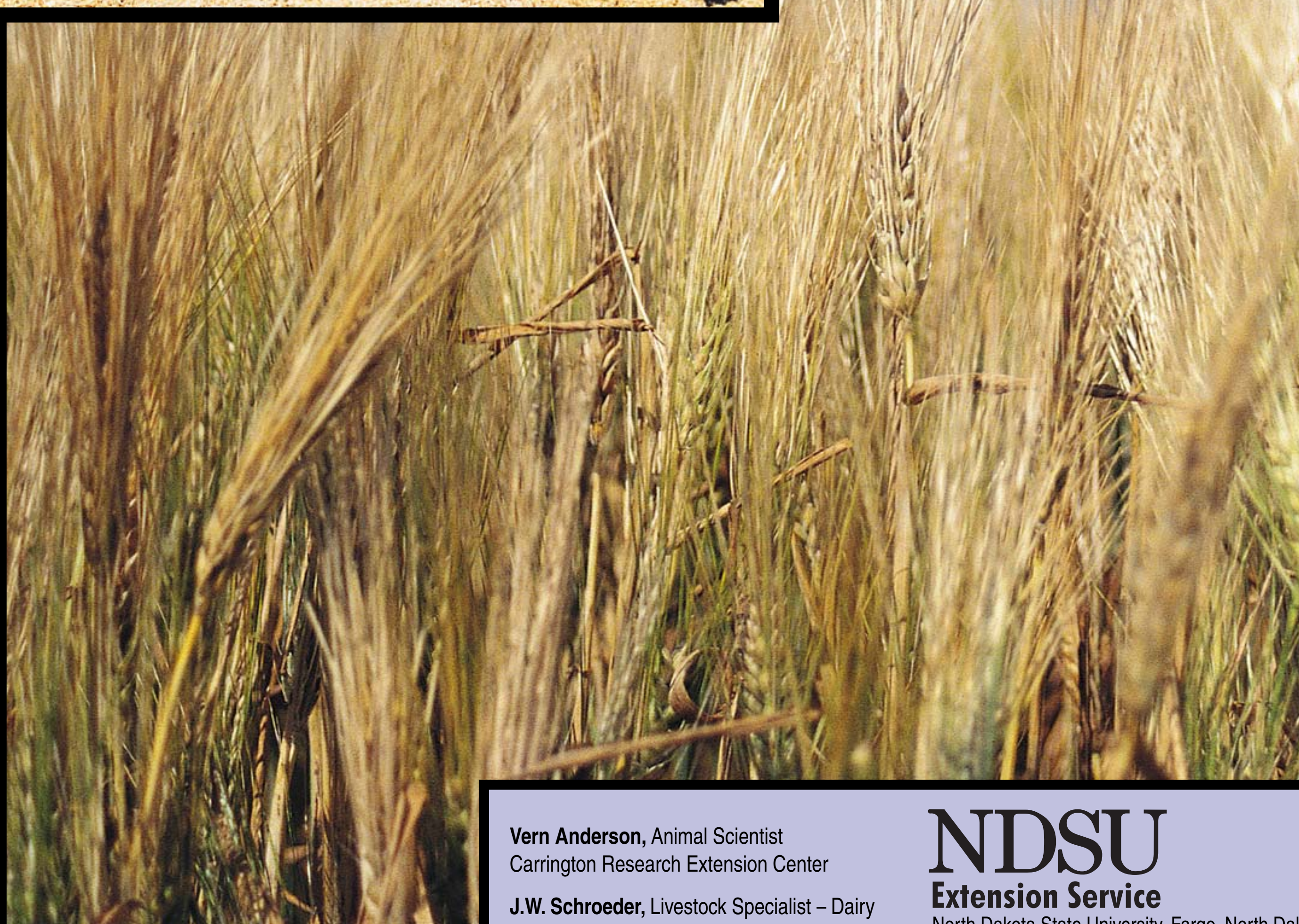
EB-72

Feeding Barley to Dairy Cattle



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Introduction

Barley is a versatile feed grain used throughout the world for a wide variety of livestock species. It is grown in temperate to sub-arctic climates with varieties developed for optimum production in respective regions. Barley is the primary livestock feed grain in the areas where it is grown. Feed barley is also transported to grain-deficit areas via truck, train, and ship. Some variation in nutrient content of barley may occur due to variety, weather, and soil fertility, but generally barley provides an excellent balance of protein, energy, and fiber.

Barley is widely used in diets for all types of dairy animals, including young calves and growing animals as well as lactating and non-lactating dairy cows. Nutrient requirements for dairy cattle vary with age and stage of production. Optimum milk production results from diets with balanced proportions of "effective" fiber, protein, energy, minerals, and vitamins. Barley is the only grain used in many northern latitude dairies and supports rolling herd averages of 21,000 to 24,000 lb (7,545 to 10,909 kg). Barley is also imported and used successfully in temperate and warmer semi-arid regions as a protein and energy source for milking herds.

Barley Grain

Barley grain is described by quality criteria as "U.S. No. 1, 2, 3, 4, 5, or Sample Grade" (Table 1). The criteria for grading barley include test weight, percent sound kernels, foreign matter, heat damage, and discoloration. Test weight is the most common quality trait used in marketing barley.

The barley kernel is composed of the hull, endosperm, and germ. The hull is the high fiber seed coat accounting for 7 to 17% of the seed weight, depending on test weight. The multi-layer endosperm (80 to 90% of seed weight) contains primarily starch and protein. The starch (energy) content is positively related to test weight and inversely related to protein concentration in the endosperm. The germ constitutes 3% of the kernel weight and contributes nitrogen (protein) and fat.

Some barley varieties are grown for malting, but increasing emphasis is being placed on breeding varieties exclusively for livestock feed. Malting barley generally has lower protein levels (<12% crude protein) than feed barley (>12% crude protein). Several types of barley have been developed (two-row, six-row, waxy, and hull-less) and a number of adapted varieties are available in most regions for two-row and six-row types.al. (1986) fed Klages and Steptoe along with other varieties. Feeding Klages increased weight gain once, resulted in no difference three times, and decreased gain twice when compared with Steptoe. Feed efficiency did not differ between varieties.

Nutrient Profile of Barley

The National Research Council (NRC) Nutrient Requirements for Dairy Cattle (1989) is a useful publication for planning diets with barley. A laboratory analysis of samples from actual lots to be used in ration formulation is highly recommended. Nutrient analyses of barley presented in Table 2 are from NRC (1989) and a three-year average of Northern Plains barley samples (Harrold and Kapphahn, 1995, 1996, 1997).

The economic feed value of barley is at least equivalent to corn on a weight basis due to higher protein content in barley, despite the slightly reduced energy levels (Anderson, 1998). Nutrient content and test weight of barley can vary somewhat within an eco-region due to variation in temperature, planting date, soil fertility, rainfall, variety, and other factors. Lighter

Table 1. Grading standards for barley.[a]

Grade	Test Weight		Sound Grain	Foreign Material	Broken Grain	Heat Damaged Kernels	Total Damaged Kernels	Discolored Grain
	(lb/bu)	(kg/hl)	(%)	(%)	(%)	(%)	(%)	(%)
U.S. No. 1	47	60.2	97	1	5	.2	2	.5
U.S. No. 2	45	58.7	94	2	10	.3	4	1.0
U.S. No. 3	43	55.1	90	3	15	.5	6	2.0
U.S. No. 4	40	51.2	80	4	20	1.0	8	5.0
U.S. No. 5	36	46.1	70	6	30	3.0	10	10.0

U.S. Sample Grade – Barley which does not fall within the grade requirements of the above grades or which contains more than 16% moisture, or contains stones, or is musty, or sour, or heating, or which has any commercially objectionable odor except of smut or garlic; or which contains a quantity of smut so great that any one or more of the grade requirements cannot be applied accurately, or which is otherwise of distinctly low quality.

[a]Adapted from the Official United States Standards for Grains, USDA, 1975.

Table 2. Nutrients[a] in barley compared to corn.

Item	Dry Matter	TDN	Crude Protein	ADF	NDF	NE_M	NE_G	NE_L	Ca	Ph	K
	(%)	(%)	(%)	(%)	(%)	(Mc/kg)	(Mc/kg)	(Mc/kg)	(%)	(%)	(%)
Barley[b]	90		12.5	7	21						
Northern Plains									.05	.39	.52
Barley[c]	88	84	13.5	7	19				.05	.38	.47
Growing Cattle						2.06	1.40				
Lactating Cows								1.94			
Corn, cracked[c]	89	80	10.0	9	3				.16	.50	.03
Growing Cattle						1.94	1.30				
Lactating Cows								1.84			
Corn, ground	88	85	10.0	9	3				.16	.50	.03
Growing Cattle						2.10	1.43				
Lactating Cows								1.96			

[a]TDN = total digestible nutrients; CP = crude protein; ADF = acid detergent fiber; NDF = neutral detergent fiber; NE_M = net energy for maintenance; NE_G = net energy for gain; NE_L = net energy for lactation; Ca = calcium; P = phosphorous; K = potassium.
[b]Harrold, R.L. and M.E. Kapphahn. 1995, 1996, 1997. Nutritional Analysis, Regional Barley Crop Quality Report. North Dakota Barley Council, Minnesota Barley Research and Promotion Council and North Dakota State University. (Includes all feed and malting barley).
[c]NRC (Nutrient Requirements of Cattle), 1989.

test weight barley exhibits higher protein and fiber content. No dairy studies have evaluated differences in performance due to test weight. Results of beef feedlot trials have been mixed. Grimson et al. (1987) reported no difference in steer performance with 85% barley rations at test weights of 37.3, 43.4, and 52.0 lb/bu (47.8, 55.6, 66.6 kg/hl). Other beef trials (Mathison et al., 1991) suggest a plateau effect with reduced digestibility and increased feed per gain at test weights below 46.0 lb/bu (59 kg/hl). Gains improved with heavier test weight barley according to Hinman (1978).

Barley is 64.6% starch, compared with corn at 71.9%, wheat at 63.8%, and oats at 44.7% (Waldo, 1973). Starch is a glucan (polymer of glucose) composed of two types of molecules, amylose and amylopectin, held together by hydrogen bonds (Rooney and Pflugfelder, 1986). Rumen microbes digest starch by releasing the enzyme α-amylase. This enzyme is used to rapidly reduce molecular size of starch and eventually produce glucose used for microbial energy. Much of the remainder is converted to volatile fatty acids or VFAs and used by the host (cow) as energy. Ruminal starch digestion of dry rolled barley is reported at 79.4% compared with 75.3% for corn with total tract digestibility for barley at 93.4% and corn at 92.5% (Kennelly et al., 1997). Waldo (1973) reported 94% of barley starch was digested in the rumen compared to 74% for corn starch, and Theurer (1986) reports 93% of barley starch digested in the rumen vs 73% for corn without regard to processing.

Processing Barley

Various processing techniques for cereal grains have been developed to increase utilization, improve palatability, and minimize negative effects on ruminal fermentation with the goal of improving animal performance. Rate, site, and extent of protein, fiber, and starch digestion may be affected by grain processing methods. Barley may be fed whole, rolled, tempered, steam flaked, ground (coarse to fine), roasted, pelleted or in some combinations of these processes.

Tempered rolled barley is the preferred processing method for dairy cows (Christen et al., 1996). Tempering is the addition of water to bring the moisture content of barley to 18 to 20%. Barley should be allowed to temper for 24 hours prior to rolling unless a wetting agent is used. The large number of small particles or "fines" produced by aggressive dry rolling or grinding provide more surface area for starch digestion to occur, resulting in increased rate of starch degradation. Fewer small particles are produced with tempered barley compared to dry rolling, resulting in reduced rate of fermentation. Rapid fermentation can lead to reduced pH and acidosis conditions in the rumen. Compared with dry rolled barley, tempering improved milk yield by 5%, feed efficiency 10%, apparent digestibility of dietary DM 6%, NDF 15%, ADF 12%, crude protein 10%, and starch 4% (Christen et al., 1996).

Heat treatment of grain may improve feed conversion by reducing ruminal degradation of barley resulting in increased starch digestion and utilization in the small intestine. Flame roasting barley decreased ruminal degradation of dry matter and crude protein although overall digestibility was not affected (McNiven et al., 1994). In a trial comparing flame-roasted barley with rolled barley, milk yield increased nearly 6.6 lb (3 kg)/day for cows fed roasted barley twice per day compared to rolled barley (McNiven et al., 1994).

If barley is fed whole, tempering is recommended, as whole kernel digestibility is greater than with dry grain. The rapid rate of passage in mixed diets with substantial amounts of forage allows little time for degradation of the intact kernel. Grinding barley, especially fine grinding, may increase the risk of acidosis. Ground barley should be fed in total mixed diets with forages and/or silages with the addition of a buffer recommended. Coarse grinding is strongly recommended over fine grinding. Pelleting, roasting, popping, and other processes may improve animal performance, but are more expensive.

Addition of $NaHCO_3$ (sodium bicarbonate) or other buffers can mitigate acid conditions in the rumen. Addition of yeast culture to dry rolled barley based steer diets increased ruminal pH for four hours after feeding and improved digestibility of forage for 12 hours. In a companion lactation study with dry rolled barley diets, addition of yeast culture improved dry matter intake by 2.6 lb (1.2 kg)/day and milk yield by 3.2 lb (1.5 kg)/day (Williams et al., 1991).

Chemical treatment of whole barley with alkali (e.g. NaOH) has an effect similar to that of rolling or crushing in allowing access of rumen microbes and digestive enzymes to the starch (Orskov and Greenbolgh, 1997). The beneficial effects of treatment of whole barley with NaOH were slower digestion, decreased fluctuation in ruminal pH, and lower incidence of ruminitis.

Using Barley in Dairy Cattle Diets

Comparison of Grains in Lactating Cow Diets

Barley included in balanced lactation rations in comparison with corn did not affect milk yield when both grains were steam rolled (Beauchemin and Rode, 1997; Beauchemin, et al., 1997); in complete mixed cubed diets (DePeters and Taylor, 1985); when barley was dry rolled and corn was ground (Grings et al., 1992); or when both grains were ground (Marx, 1984; Moss et al., 1976; Park, 1988; Rode and Satter, 1988). Dry rolled sorghum and dry rolled barley produced similar milk yield with a tendency for improved feed efficiency with barley (Santos et al., 1997). Ground barley and rolled hull-less oat diets resulted in similar milk yield and milk protein (Fearon et al., 1996). Dry rolled barley and ground corn diets were compared with and without bovine somatotropin (bST) administration. Efficacy of bST, milk yield, composition, somatic cell count, and cow weight were similar for both grains sources (Eisenbeisz et al., 1990). Still others did notice slightly lower milk production and dry matter intake in cattle fed barley in place of corn (Casper and Schingoethe, 1989; McCarthy et al., 1989). The increase in ruminal fermentation of starch from barley can alter pH and potentially decrease cellulolytic activity of rumen bacteria. Thus, a few discrepancies can be found under certain, but undetermined, dietary or geographical factors.

Protein

Protein requirements for dairy cows are calculated as either crude protein or ruminally degradable/undegradable protein. High producing dairy cows require more ruminally undegradable protein (NRC, 1989) than previously known. Undegradable protein is protein that escapes ruminal digestion and is digested by enzymes and absorbed into the blood directly from the lower gastrointestinal tract. Any process, such as tempering or heating, that reduces the rate of ruminal fermentation enhances the feed value and undegradable portion of crude protein in barley.

Fiber

High producing cows require excellent quality forage that provides “effective” fiber in the rumen. Effective fiber stimulates chewing and ruminating, critical activities for thorough digestion and maintenance of stable ruminal pH. Fiber is characterized as neutral detergent fiber (NDF) or acid detergent fiber (ADF). Use NDF as a measure of the cell wall constituents, indicating bulkiness of the diet. Application of the level of ADF is essentially an indication of the indigestible lignin and cellulose components of forage. Reduced fiber digestibility was observed with barley diets (DePeters and Taylor, 1985) and is probably caused by reduction in ruminal pH due to the rapid fermentation rate of barley.

Fiber concentrations in dairy cattle diets are variable because of the composition of concentrates (Weiss et al., 1989) and source and maturity of forages (Mertens, 1983). The NRC (1989) recommends a minimum of 25 to 28% NDF in the total diet, with 75% of the NDF fraction provided by forages. This level will maintain optimum rumen function and avoid potential milk fat depression which occurs at reduced forage levels. High barley diets may provide more NDF from grain, which could effect digestion based on the proportion of forage NDF added (Varga and Hoover, 1983).

Beauchemin and Rode (1996) suggest the minimum amount of forage should be greater for barley-based lactation diets to maintain optimum pH in the rumen. Populations of fiber-digesting bacteria and starch-digesting bacteria occur in a dynamic state in the rumen with greater growth based on proportion of preferred substrate in the diet. Both are required at some degree of equilibrium for optimum digestion. Decreased pH in the rumen changes the proportions of volatile fatty acids (VFA) by decreasing acetate, which is required for milk fat synthesis, to increasing propionate. Populations of cellulolytic (fiber digesting) bacteria can be maintained in the rumen as long as pH is maintained above 6.2. Addition of yeast cultures and tempering grain can also help stabilize ruminal pH. However, the quality and digestibility of forage are still major factors in developing diets for optimum milk production.

Management of Barley Diets

Good nutritional management is important to optimize milk production. Recommended practices include feeding tempered rolled barley in total mixed rations (TMR) or feeding small amounts several times during the day. Some dairymen feed small amounts of barley before and after each milking with research results supporting improved dry matter intake and yield of milk, protein, and lactose (Robinson and McNiven, 1994). Feeding individual cows according to milk production is the most efficient use of feed but requires added labor or automated equipment. Practices such as feeding in a total mixed ration (TMR) are very useful for feeding barley. Major ration changes should be made in small increments over a minimum of two to three weeks to allow rumen microbial populations to adapt to changing feeds.

Mineral supplementation is usually required for all lactation diets as grains are high in phosphorus and extra calcium is needed to achieve the desired calcium to phosphorus ratio of 1.6 to 1. Barley has more than 10 times as much potassium as corn (Table 2) but may require slightly more calcium for the correct ratio in the complete ration.

Growing and Bred Heifers

Protein, energy, and fiber are essential for growing calves, and barley can contribute to balanced rations for these animals. Total mixed diets with modest grain levels are often used for growing and bred replacement heifers. Starter diets with high protein barley as a replacement for soybean meal have been formulated and successfully evaluated for young calves (Munck et al., 1969). Maiga et al. (1994) found body weight gain on barley- based diets was nearly that of corn-based diets and depended on associative effects of feeds and experimental conditions. Barley is cost competitive in growing diets and simplifies ration formulation by reducing the number of other ingredients.

Table 3. Recommended nutrient concentrations in diets of lactating dairy cattle (1300 lb [590 kg] cow producing 4.0% milkfat and gaining 0.7 lb [0.3 kg] per day).[a]

	Milk Yield (kg/day)					Early	Lactation
	10	21	32	42	53		
	Milk Yield (lb/day)					Dry Cow	
	23	47	70	93	117	Pregnant	(0-3 weeks)
Nutrient[b]							
	Mcal/kg of Dry Matter						
Energy, NE_L	1.43	1.52	1.61	1.72	1.72	1.25	1.67
	Mcal/lb of Dry Matter						
	0.65	0.69	0.73	0.78	0.78	0.57	0.76
	Percent of Diet Dry Matter						
TDN	63	67	71	75	75	56	73
CP	12	15	16	17	18	12	19
Fiber							
ADF	21	21	21	19	19	27	21
NDF	28	28	28	25	25	35	28
Minerals							
Ca	0.43	0.53	0.60	0.65	0.66	0.39	0.77
P	0.28	0.34	0.38	0.42	0.41	0.24	0.49
Mg	0.20	0.20	0.20	0.25	0.25	0.16	0.25
K	0.90	0.90	0.90	1.00	1.00	0.65	1.00

[a]Adapted from NRC Dairy, 1989.
[b]NE_L = net energy for lactation; TDN = total digestible nutrients; CP = crude protein; ADF = acid detergent fiber; NDF = neutral detergent fiber; Ca = calcium; P = phosphorous; Mg = magnesium; K = potassium.

Disease

The only mycotoxin associated with growing barley has been deoxynivalenol (DON), commonly referred to as vomitoxin. Vomitoxin is caused by fusarium head blight (scab), which occurs in barley and wheat during periods of high moisture and humidity during the early heading stages. However, experiments suggest its presence in the grain has no effect on feed intake or milk yield of lactating cows for all levels tested (Anderson et al., 1996; Charmley et al., 1993; Ingalls, 1996).

Concentrate feeding, regardless of source, has not been implicated as a cause of lameness in production dairy cattle; however, cows fed high amounts of grain experienced greater incidence of lameness (Kelly and Leaver, 1990). High levels of ground cereals are a predisposing factor to lameness, a direct result of subclinical acidosis in the rumen. Care should be taken in feeding any ground cereal grain at high levels. Additives, such as yeasts or buffers, may be useful.

Age, stage of lactation, and milk production level are key factors when considering nutrient requirements (NRC, 1989) for dairy cattle (Table 3). Diets fed to higher producing cows are lower in fiber and more nutrient dense, resulting in increased intake and increased nutrient consumption per unit of intake. Diets fed to cows with less milk production potential should be higher in fiber and lower in energy and protein. Optimum returns occur when cow diets are formulated to meet requirements and production potential.

Conclusions

Barley is a very useful grain source for growing, gestating, and lactating dairy cattle, providing more protein than most other grains, highly digestible starch (energy), and useful fiber. Cows fed diets with barley as the primary concentrate produce the same amount of milk as cows fed other grains. Processing barley by tempering and rolling improves digestion in the rumen, feed efficiency, and animal performance. Feeding properly processed barley with the appropriate amount and quality of forage in mixed rations maintains optimum ruminal pH and nutrient digestibility. Addition of yeast culture appears to be beneficial. Barley is an economical nutrient source that should be strongly considered in formulating rations for dairy cattle.

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